

C0 LOW- β OPTICS

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ABSTRACT

A low- β insertion has been designed for the BTeV experiment at C0. With ± 12 m for detector space, a β^* of 0.5 m can be achieved using 170 T/m magnets in the final focus triplets. A total half-crossing angle of 240 μ r is necessary to keep the beams separated by 5σ at the 2nd parasitic crossing. There are 2 possible Tevatron collision scenarios: B0 & D0, but not C0, and; C0, but not B0 or D0.

1. DESIGN CONSIDERATIONS

Given the advanced state of operational plans for Run IIb (132 nsec bunch spacing) a new C0 Interaction Region (IR) insertion should be capable of operating in a manner that does not impact nominal Run IIb Tevatron parameters. This implies creating an entirely localized insertion – one which is completely transparent to the rest of the machine. This constraint has several important design implications, some of which are pointed out below.

- An IR design similar to that employed at CDF & D0 is unacceptable as a C0 candidate. The addition of such a (single) low- β region to the machine would raise the tune by a half-integer in each plane, moving them far from the standard operating point and smack onto the 21.0 integer resonance. The nominal (fractional) tunes can most elegantly be retained by adding 2 low- β 's locally in each plane, thereby boosting the machine tunes by a full integer.
- The B0 & D0 IR's are not optically-isolated entities. Progression through the low- β squeeze involves adjusting, not only the main IR quadrupoles, but also the tune quad strings distributed around the ring. The result is that the lattice functions at any point in the ring, and the phase advances across any section of the ring, are not fixed quantities, but vary through the squeeze sequence. The C0 insertion must be sufficiently flexible to track these elusive matching conditions.

- With collisions only at B0 & D0 the unit transfer matrix added by the C0 insert ensures that the incoming & outgoing helices are automatically matched into the established Run IIb values. To maintain this match with collisions at all 3 IP's, however, would require additional separators in the short B0 \rightarrow C0 & C0 \rightarrow D0 arcs. There is no space available for more separators, so controlled, useful collisions can only be created at B0 & D0, or just C0, but not all three simultaneously. Furthermore, without new arc separators the 2 IP collision options – B0 & C0 or D0 & C0 – are also excluded.

2. PHYSICAL LAYOUT

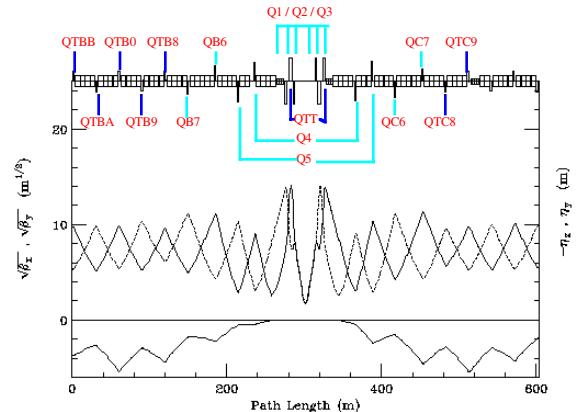


Fig.1. Power circuits of the IR quadrupoles.

Both the series & independent IR quad circuits are illustrated in Fig. 1¹. The magnets required fall into 3 gradient ranges. There are LHC-like magnets operating at or below 170 T/m. This is substantially less than the >220 T/m LHC design, but the gradients are limited here by the Tevatron 4.2K cryogenics. The high-field 140 T/m Q1 quadrupoles removed from CDF & D0 for Run II are also used. And there are strong (≤ 40 T/m) correction spools for the final optical match into the arcs.

¹ The complete survey of the B38 \rightarrow C21 region is attached as Appendix I.

Composition of the quadrupole circuits is described below, with the indicated lengths being magnetic lengths.

- The triplets:

Q1	: 96.5"	170 T/m
Q2	: 173.5"	170 T/m
Q3	: 96.5"	170 T/m

A schematic layout of an IR triplet is given in Fig.2, showing the slot lengths & magnetic lengths of the elements, and spaces allocated for flanges, cryo, coil supports, whatever. A special correction package is installed between the Q2 & Q3 magnets. This contains both vertical & horizontal BPM's, dipole correctors, plus a very short, strong (~40 T/m) trim quad. The dipole correctors are ideally situated for beam control at the IP; $\beta_x = \beta_y > 60\% \beta_{max}$, and the betatron phase advance to the IP is almost exactly 90° in both planes. Unlike the triplets at CDF & D0, the final focus magnets here are powered in series, and independent variation of the small QT quad's gradient is sufficient to complete the match to the appropriate IP optics.

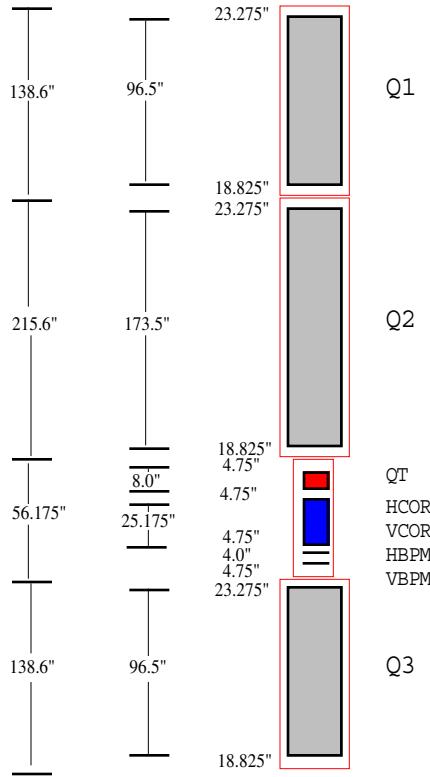


Fig.2. Details of the IR triplets.

- B48/C12 & B47/C13:

Q4	: 75"	170 T/m
Q5	: 54"	170 T/m

Apart from their magnetic lengths the Q4 & Q5 magnets are the same design as the triplet quadrupoles, having 18.825" of space at one end of the cryostat & 23.275" at the other to accommodate the necessary ancillary hardware (see Fig. 2). These quadrupoles are accompanied by new, short (56.175") spools, containing a BPM, dipole corrector, and sextupole trim. These spools also serve as the magnet power feeds & transport the main bus.

- B46 & C14:

Q6	: 55.19"	140 T/m
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The regular 66" arc quads and their spools at B46 & C14 are replaced by independently-powered (existing) high-field 55" magnets plus new, short (44.175") spools identical to those at the Q4 & Q5 locations.

- B45 & C15:

Q7	: 55.19"	140 T/m
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At B45 & C15 the Tevatron 66" arc quads and their short spools are replaced by independently-powered (existing) 55" quadrupoles plus new, short (44.175") spools which provide the power feed to the magnets plus contain a dipole & sextupole corrector .

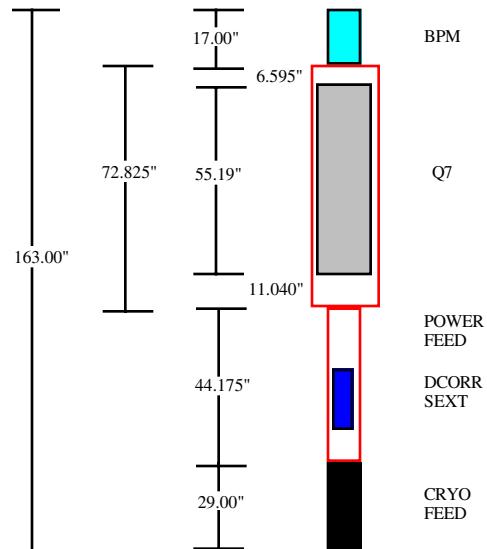


Fig.3. B45 / C15 slot layout.

- B38 → B44 & C16 → C17:

The QTBA trim quad spool (B39) is not used in this optical design, but all the remaining trim quads – QTB8 → QTBB, and QTC8 & QTC9 – are of the 25", strong, 40 T/m variety.

Non-standard separations appear between some of the insertion's inner arc quadrupoles. Between the B48 & B47 [C12 & C13] quadrupoles space is reduced by 1 dipole, whereas between B46 & B45 [C14 & C15] separation increases by 1 dipole slot length. Extensive simulations have shown this configuration contributes markedly to the robustness of the IR's tuning range.

Trim quads are allocated in a lop-sided configuration, with 2 more installed in the upstream end of the insert. In B-sector it is possible to extend insert elements a good distance back into the arc before interfering with Run IIb operations. Not so in C-sector. The 4 vertical separators at C17 are integral components of Run IIb controls and, therefore, define the downstream insert boundary.

3. OPTICS

There are 15 optical constraints the insertion satisfies. The 6 incoming Twiss parameters are matched at the IP to $\beta_x^* = \beta_y^* \equiv \beta^*$, $\alpha_x^* = \alpha_y^* \equiv 0$, $\eta^* \equiv 0$, $\eta'^* \equiv 0$, and then matched back into the nominal arc values at the downstream end of the insert (at C17). The fractional Run IIb phase shifts, $\Delta\mu_x$ and $\Delta\mu_y$, are preserved across the insert. The final constraint imposed in the design is that $\beta_{\max}(x) = \beta_{\max}(y)$ in the triplets each side of the IP. While this last restriction isn't really crucial, it is the best choice, minimizing the consumption of aperture in the low- β quads.

In the injection lattice, shown in Fig.4, $\beta^* = 2.60$ m results in a β_{\max} of 228 m in the triplets. This is slightly less than the >240 m of the B0 & D0 injection lattices and, so, is not anticipated to pose any problems for Tevatron operations. [The *maximum* β^* (*minimum* β_{\max}) at injection is determined, not by gradient limitations, but by beam separation at the IP. See Sections 4.1 & 5].

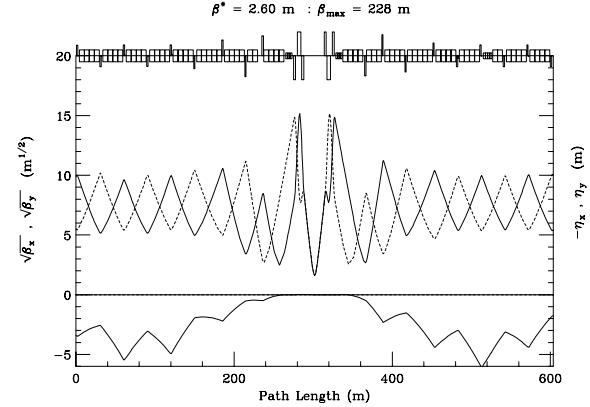


Fig.4. C0 injection optics

Tevatron Collider experience suggests that the smallest realistic β^* attainable is limited by the good-field aperture and, therefore, β_{\max} in the low- β triplets, rather than by any gradient limitations of the IR quads. In the current model the Q1 magnets at C0 are roughly 15' farther from the IP than the corresponding ones at B0 & D0. As a result, β_{\max} is considerably larger at C0 for any given value of β^* . With $\beta^* = 50$ cm, β_{\max} has already grown to 1163 m (Fig.5), which is comparable to the β_{\max} for $\beta^* = 35$ cm at the other IP's.

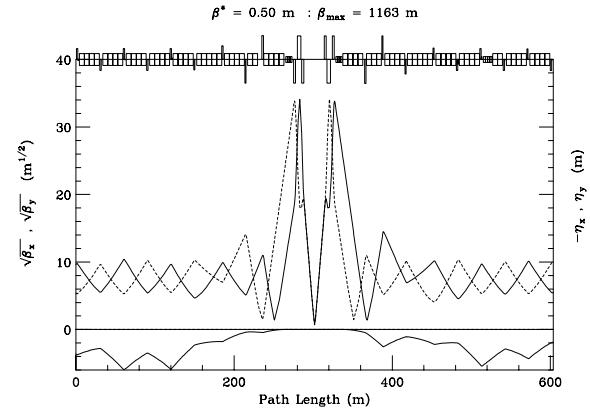


Fig.5. C0 collision optics

3.1. LOW- β^* SQUEEZES

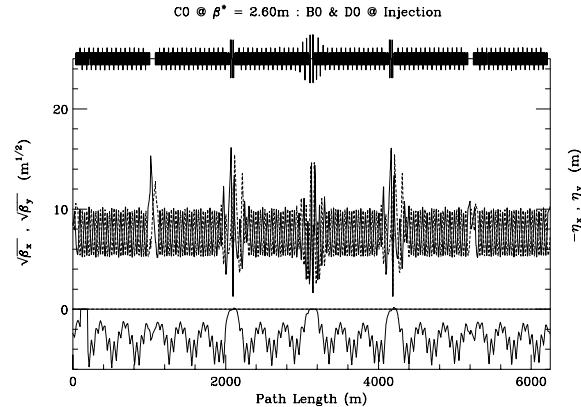
Every stage of the squeeze from $\beta^* = 2.60 \rightarrow 0.50$ m at C0 can match exactly to any step in the B0 & D0 Injection $\rightarrow \beta^* = 0.35$ m squeeze. The following pages illustrate the lattice functions & tabulate the C0 quadrupole gradients corresponding to the extremes of this operational matrix.

- (1) $\beta^* = 2.60$ @ C0 : $(\beta_x^*, \beta_y^*) = (1.61, 1.74)$ @ B0/D0
- (2) $\beta^* = 2.60$ @ C0 : $\beta^* = 0.35$ @ B0 & D0
- (3) $\beta^* = 0.50$ @ C0 : $(\beta_x^*, \beta_y^*) = (1.61, 1.74)$ @ B0/D0
- (4) $\beta^* = 0.50$ @ C0 : $\beta^* = 0.35$ @ B0 & D0

(Without additional arc separators, the combination of $\beta^* = 0.50$ m at C0 with $\beta^* = 0.35$ m at B0 & D0 has no operational value and is included here only for the sake of completeness & academic interest).

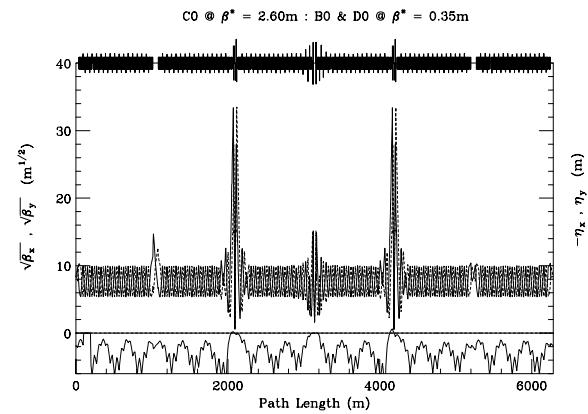
All gradients in the following tables reflect 1 TeV/c operations. Highlighted entries indicate magnets that must change polarity at some point during the transition between the various operating modes.

3.1.1. $\beta^* = 2.60$ @ C0 : $(\beta_x^*, \beta_y) = (1.6, 1.7)$ @ B0/D0



Quad #	$C0 @ \beta^* = 2.60$ m B0 & D0 @ $(\beta_x^*, \beta_y^*) = (1.61, 1.74)$ up down	
Q1	-167.520	167.520
Q2	167.520	-167.520
Q3	-167.520	167.520
QT _T	37.696	-37.696
Q4	143.736	-143.736
Q5	-148.937	148.937
Q6	116.180	-121.899
Q7	-91.884	94.789
QT ₈	7.438	-24.221
QT ₉	10.731	-5.304
QT ₀	4.929	
QTA	0.0	
QT _B	0.317	

3.1.2. $\beta^* = 2.60$ @ C0 : $\beta^* = 0.35$ @ B0 & D0



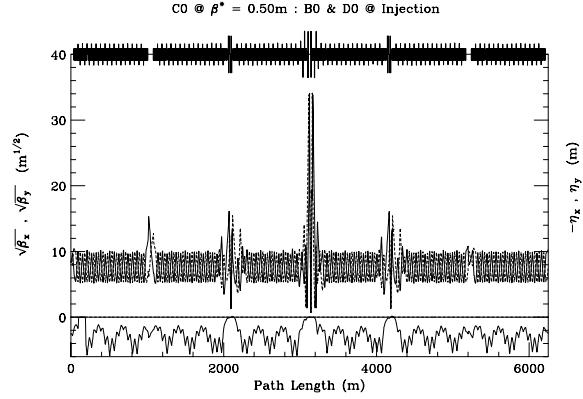
Quad #	C0 @ $\beta^* = 2.60$ m B0 & D0 @ $\beta^* = 0.35$ m up down	
Q1	-167.997	167.997
Q2	167.997	-167.997
Q3	-167.997	167.997
QT _T	17.806	-17.806
Q4	140.691	-140.691
Q5	-147.714	147.714
Q6	111.184	-114.454
Q7	-90.388	90.082
QT ₈	11.860	-15.710
QT ₉	1.663	-2.752
QT ₀	5.168	
QTA	0.0	
QT _B	1.455	

Tables 3.1.1 & 3.1.2 list the C0 quad gradients corresponding to the endpoints of an operating scenario in which β^* at C0 is fixed at 2.60 m while β^* at B0 & D0 is squeezed from the Injection values $\rightarrow \beta^* = 0.35$ m for collisions. At each step of this low- β squeeze the C0 magnets are adjusted to maintain the optical match to the 'appropriate', ever-changing lattice functions & phase advances across the insert. The following table indicates the extent to which these gradients must vary during the B0 & D0 squeeze.

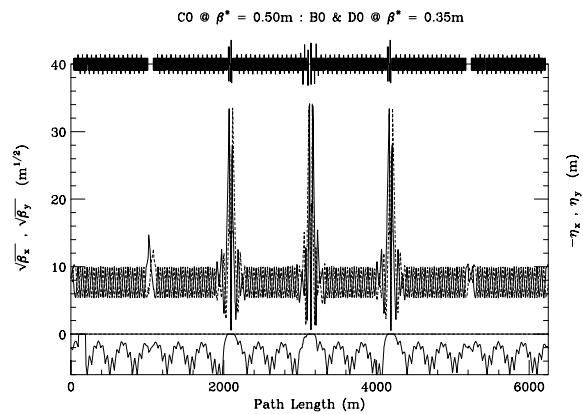
C0 Gradient Variations			
C0 Fixed @ $\beta^* = 2.60$ m B0 & D0 Squeeze : $(\beta^{*x}, \beta^{*y}) = (1.61, 1.74) \rightarrow \beta^* = 0.35$ m			
	B' [max] T / m	B' [min] T / m	$\Delta \int B' \cdot ds$ T.m/m
Q1 / Q3	167.997	167.520	1.169
Q2	167.997	167.520	2.102
QT _T	37.696	17.806	4.042
Q4	143.736	140.691	5.801
Q5	148.937	147.714	1.677
QB6	116.180	111.184	7.004
QC6	121.899	114.454	10.437
QB7	91.884	90.388	2.097
QC7	94.789	90.082	6.598
QT _B 8	11.860	7.438	2.808
QT _C 8	24.221	15.710	5.404
QT _B 9	10.731	1.663	5.758
QT _C 9	5.304	2.752	1.621
QT _B 0	5.168	4.929	0.152
QT _B A	0	0	0
QT _B B	1.455	0.317	0.723

3.1.3. $\beta^* = 0.50$ @ C0: $(\beta^{*x}, \beta^{*y}) = (1.6, 1.7)$ @ B0/D0

Quad #	C0 @ $\beta^* = 0.50$ m B0 & D0 @ $(\beta^{*x}, \beta^{*y}) = (1.61, 1.74)$ up down	
Q1	-166.421	166.421
Q2	166.421	-166.421
Q3	-166.421	166.421
QT _T	0.268	-0.268
Q4	167.764	-167.764
Q5	-166.247	16.247
Q6	95.005	-102.514
Q7	-72.795	80.691
QT _B 8	10.020	-32.941
QT _B 9	-0.958	19.056
QT _B 0	-2.622	
QTA	0.0	
QT _B B	-6.498	

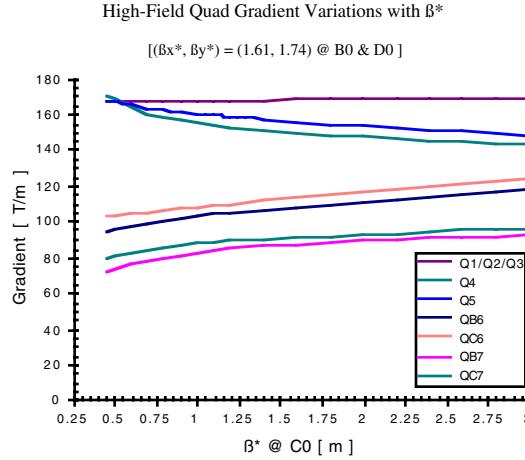


3.1.4. $\beta^* = 0.50$ @ C0 : $\beta^* = 0.35$ @ B0 & D0



Quad #	C0 @ $\beta^* = 0.50$ m B0 & D0 @ $\beta^* = 0.35$ m up down	
Q1	-167.257	167.257
Q2	167.257	-167.257
Q3	-167.257	167.257
QT _T	6.7203	-6.7203
Q4	156.618	-156.618
Q5	-162.995	162.995
Q6	87.505	-91.247
Q7	-71.738	74.967
QT _B 8	11.380	-22.750
QT _B 9	-6.271	17.547
QT _B 0	-7.268	
QTA	0.0	
QT _B B	0.317	

With β^* at B0 & D0 fixed at their injection values of $(\beta_{x^*}, \beta_{y^*}) = (1.61, 1.74)$ m, the following graph illustrates the high-field quad gradient variations through the C0 squeeze : $\beta^* = 2.60$ m $\rightarrow \beta^* = 0.50$ m.



4. BEAM SEPARATION

To reduce the number of interactions per crossing at the IP's, it is planned in Run IIb to reduce bunch spacing in the Tevatron from 396 \rightarrow 132 nsec. With the first parasitic crossings then occurring just 19.86 m from the IP's, though, it is realized that crossing angles must be introduced to obtain separated beams at these points².

Collider operation with crossing angles has at least 2 major consequences. First, luminosity is reduced due to the decreased overlap of the beams at the IP. A compromise must therefore be reached between minimizing the beam-beam tune shift from the first parasitic crossings (large $\theta_{1/2}$) & minimizing the luminosity reduction (small $\theta_{1/2}$). The second impact of crossing angles is to produce separated beams in the low- β final-focus quadrupoles – precisely where β already reaches its ring-wide maximum. With head-on collisions the Collider currently operates with $\beta^* = 35$ cm, and β_{max} in the triplets is then ~ 1100 m. It is generally suspected (though not verified) that the minimum β^* attainable is limited by the adverse impact on the beam by high-order multipoles in the low- β quadrupoles. The consequences of sending

beams off-axis through the magnets as well is not well understood – the Tevatron has never been operated before with crossing angles.

Beyond the decisions to implement shorter bunch spacing & crossing angles in Run IIb, many details of collision scenarios have not been finalized. Significantly, for instance, there is no 'official' helix to describe Collider operations in this era – several promising candidates exist – and even the final locations of separators have not yet been established. The collision helix assumed for the purposes of the current study should be viewed, therefore, as only the latest *helix du jour*, and might be quite different in detail from the eventual configuration. In this version³ the half-crossing angles at B0 & D0 are $(x^{*\prime}, y^{*\prime}) = (+170, -170)$ μ rad, giving 5σ of separation at the 1st crossing for $\beta^* = 35$ cm, and 20π emittance (95%, normalized) beams.

4.1. C0 WITHOUT COLLISIONS

With collisions at just B0 & D0, the optics at C0 remain at the injection value of $\beta^* = 2.60$ m, and the B49 & C11 separators are turned off. The resulting matched helix from B38 \rightarrow C21 is shown below. Beam separation is $\geq 5\sigma$ everywhere, but is poorest at the IP. It is this feature of the model that determines β^* at injection. For $\beta^* > 2.60$ m ($\beta_{max} < 228$ m) beam separation drops below 5σ . (In Section 5 it is shown that this trait can be used to create C0 collisions, at some level).

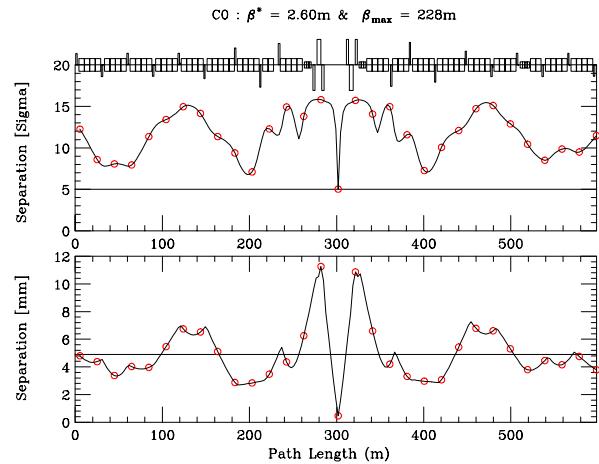


Fig.6. Separation at C0 during B0 & D0 collisions.

² 132 nsec Bunch Spacing in the Tevatron Proton-Antiproton Collider, S.D. Holmes, *et al.*, TM-1920.

³ "v3h15acsb4.nppn.170pnpn", Peter Bagley, private communication.

4.2. C0 WITH COLLISIONS

For collisions at C0 the optics at B0 & D0 remain in their Injection configuration. In this case, all the separators in the ring become available for bringing beams together at the C0 IP, while keeping them separated everywhere else. For half-crossing angles at C0 of $(x'^*, y'^*) = (-170, +170)$ μrad , one possible (minimal) separator solution is given in the table below. The selection of separators has not been optimized in any way, other than to ensure adequate beam separation around the ring. Many, many more combinations can be explored.

Separator Gradients (MV/m)					
Horizontal			Vertical		
A49	2	2.32078	A49	1	2.32078
B11	1	-2.32078	B11	2	-2.32078
B17	4	-0.99823			
B49	2	-4.0	B49	1	4.0
C11	1	4.0	C11	2	-4.0
			C17	4	0.22304
C49	2	1.19549	C49	1	1.19549
D11	1	-1.19549	D11	2	-1.19549

The following figures illustrate the beam separation across the insert from B38 → C21, and the separation all around the ring. With this separator solution the closest approach through the insert is at the 2nd parasitic crossing, where separation is about 5σ . Elsewhere in the ring, separation drops close to 7σ in the vicinity of A0, but otherwise the average separation is $10 \rightarrow 13\sigma$. Oscillations in the helix could be further smoothed using a larger subset of separators.

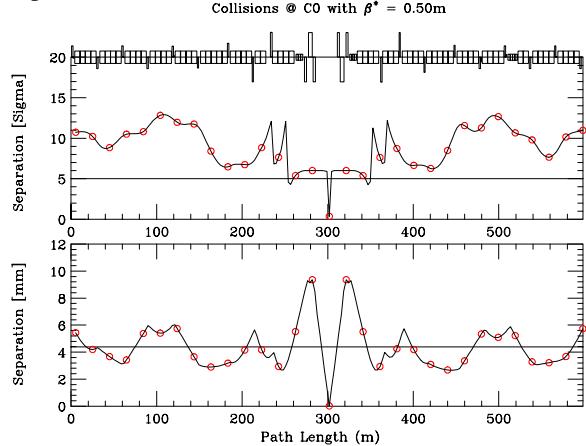


Fig.7. Beam separation through the C0 insert during C0 collisions.

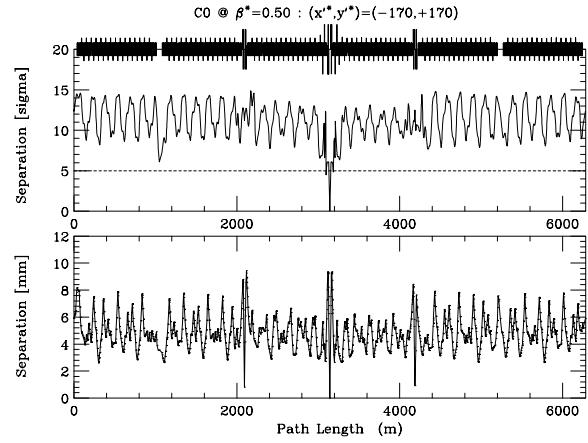


Fig.8. Beam separation around the entire ring during C0-only collisions

5. B0 & D0 COLLISIONS — PLUS POORBOY COLLISIONS @ C0

There are just 5 sets of separators in each plane between B0 & D0, including the new B49 & C11 modules. With the B0 & D0 crossing angles fixed at $(x'^*, y'^*) = (+170, -170)$ μrad it is not possible to control beam position & angle at the C0 IP while simultaneously maintaining adequate beam separation through the arcs⁴. However, if the desire for complete beam control at C0 is relinquished, collisions *can* be created, but at a reduced luminosity. This option might or might not be of interest to BTeV.

The expression for luminosity can be written in a form that separates factors common to all 3 IP's from those which are IR-dependent:

$$L = \frac{f \cdot N_1 N_2}{4\pi \cdot \sigma_l \cdot \varepsilon_{N_{95}} / 6} \cdot F(\beta^*, \theta_{1/2})$$

The form-factor F contains the information related to transverse beam size & crossing angles at the IP⁵:

$$F(\beta^*, \theta_{1/2}) \equiv \frac{2}{\sqrt{\pi}} \cdot e^{-z^2 \theta^2} \cdot \int_0^\infty \frac{d\mu}{(1+\mu^2)} \cdot \exp \left\{ -z^2 \mu^2 + \frac{z^2 \theta^2}{(1+\mu^2)} \right\}$$

where θ and z are defined in terms of β^* and the total half-crossing angle $\theta_{1/2}$ as:

$$\theta = \theta_{1/2} \cdot \frac{\sigma_\perp}{\sigma_t}, \quad z = \beta^* / \sigma_\perp$$

⁴ Conceptual Designs for IR Optics at C0, John A. Johnstone, TM-2122

⁵ This expression for F is valid for $|x'^*| = |y'^*|$.

The numerical value of F can be used as a figure of merit for any given collision configuration. At B0 & D0, with $\beta^* = 0.35$ m & $\theta_{1/2} = 240 \mu\text{r}$, $F(0.35, 240) = 1.031$. At C0, with $\beta^* = 0.50$ m & $\theta_{1/2} = 240 \mu\text{r}$, the form-factor $F = 0.823$.

Subsequent sections outline 2 techniques for creating high- β^* parasitic collisions at C0 which do not disrupt the nominal Run IIb collision conditions at B0 & D0.

5.1 HIGH- β^* COLLISIONS & NO SEPARATORS

With the B49 & C11 separators off, simply raising β^* at C0 brings the beams into collision. Fig.9 illustrates beam separation through the C0 insertion when β^* is raised from the 2.60 m injection value to 3.64 m. At the IP $(x^*, y^*) = (-6.31, +6.31) \mu\text{m}$, with half-crossing angles of $(x'^*, y'^*) = (-179, +168) \mu\text{rad}$. The beam centers are slightly offset at the IP; 'separated' by 17.8 μm , or a mere 0.16σ for 20π emittance beams.

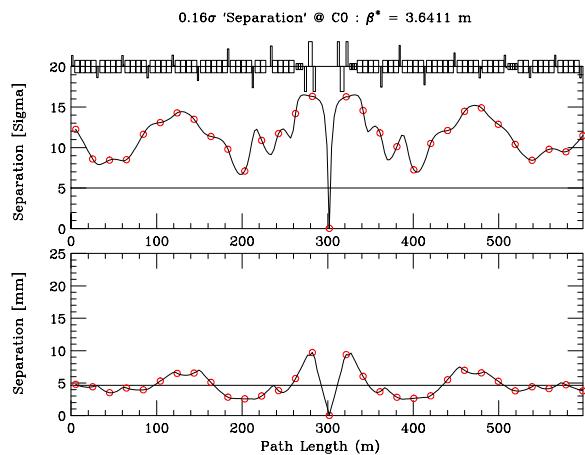


Fig.9. "Near" collisions at C0, synchronous with B0 & D0 collisions

Ignoring the small offset at the IP, and small difference between the x & y crossing angles, the luminosity form-factor is $F(3.641, 245.5) = 0.209$. The offset at the IP is estimated to reduce this value by < 5%. So, this approach for creating parasitic C0 collisions would result in a C0 luminosity $\approx 1/5$ the value at B0 & D0, and $\approx 1/4$ the nominal C0 luminosity with $\beta^* = 0.50$ m.

5.2 HIGH- β^* COLLISIONS WITH SEPARATORS

By very slightly adjusting the gradients (<<1%) of just 1 additional separator in each plane of the short B0→C0→D0 section, collisions can be created at C0 without impacting B0 & D0 collisions or noticeably altering beam separation through the arc.

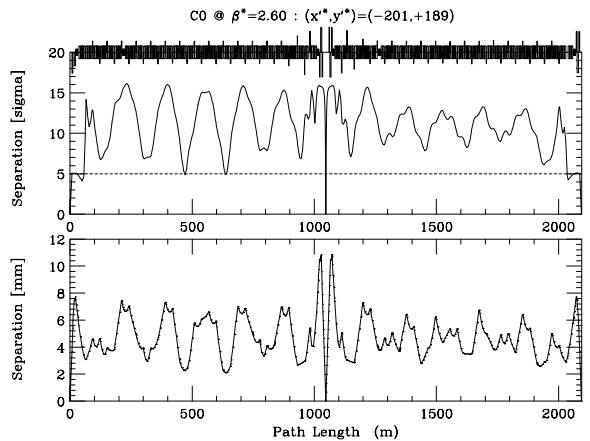


Fig.10. B0, C0, & D0 collisions : $\beta^* = 2.60$ m @ C0

Separator Gradients (MV / m)					
Run IIb Nominal		B0,C0, & D0 Collisions			
B11H	1	-4.18408	B11H	1	-4.18496
B11V	2	-4.10724	B11V	2	-4.10660
B49H	2	0.0	B49H	2	-3.33144
B49V	1	0.0	B49V	1	-3.26163
C11H	1	0.0	C11H	1	-3.55194
C11V	2	0.0	C11V	2	-3.05772

With crossing angles of $(x'^*, y'^*) = (+170, -170) \mu\text{rad}$ fixed at B0 & D0, Fig. 10 & the accompanying table illustrate one possible separator solution leading to C0 collisions. At C0 β^* remains at the injection value of 2.60 m & the total half-crossing angle becomes $275.9 \mu\text{rad}$, giving $\approx 16\sigma$ separation at the 1st parasitic crossing. The beams are not offset at the IP, and the form-factor $F(2.60, 275.9) \approx 0.254$. At C0, therefore, luminosity is $\approx 1/4$ that at B0 & D0, and $\approx 1/3$ the nominal C0 luminosity with $\beta^* = 0.50$ m.

Very modest gains in F can be realized by lowering β^* . However, the limiting factor with this approach is the fairly alarming rate at which beam separation increases in the triplets.

6. SUMMARY

By adding an integer of betatron phase advance locally at C0, a low- β^* insert can be designed that is optically transparent to the rest of the Tevatron, with no impact on nominal Run IIb machine operating parameters.

IR quadrupole construction uses 2 (new) technologies:

- The final-focus triplets plus Q4 & Q5 magnets are LHC-like designs, operating at gradients up to 170 T/m. These are 4 separate magnetic lengths, but otherwise the physical designs are imagined to be identical.
- Strong quadrupole correctors are needed for the final optical match into the arcs. These magnets are analogous to the TSM/TSN-series correctors at the B0 & D0 IR's, but with significantly weaker fields (25 T·m/m *c.f.* 38 T·m/m). The C0 IR design currently calls for six such correctors, but very likely this number could be reduced to four.

For C0 collisions β^* is probably limited to ≥ 50 cm by β_{\max} in the triplets. However, in the event that aperture in the triplets does not present a problem, β^*

could be reduced to < 35 cm ($\beta_{\max} > 1660$ m). The single design modification necessary would be to grow the Q4 magnetic length from 75" to ≈ 78 " in order to maintain gradients below 170 T/m.

New separator modules are installed at the B49 & C11 locations. These are ideally situated for position control at the IP during C0-only collisions. And it was also shown that these separators could be useful in creating B0, D0, *plus* C0 collisions, albeit at reduced luminosity. However, there are insufficient separators through the short $B0 \rightarrow C0 \rightarrow D0$ arc to provide independent position & angle control at all 3 IP's simultaneously. Collider operations, therefore, are limited to just two possibilities: either B0 & D0 are at collision, or only C0 has collisions.

Chromatic compensation is an important concern that went unaddressed in the current report. The addition of the new low- β insert has a huge impact on chromaticity, changing the machine's natural chromaticities by $(\Delta v_x, \Delta v_y) = (-19.75, -19.70)$. If the C0 insertion is to be truly transparent to the rest of the Tevatron, the next iteration on the IR design must devise a local sextupole correction scheme for chromatic compensation.

$$\Omega$$

APPENDIX I : SURVEY FROM B38 → C21

[DIPOLES ARE INDICATED ONLY BY ENTRANCE & EXIT MARKERS]

12/27/00 -- END @ X= -38.106695, Z= +299.798F72, THETA = -0.2760055561

Survey of beam line CHEAPIE

E L E M E N T S E Q U E N C E		I	P O S I T I O N	I	A N G L E	I
pos.	element occ. no.	arc no.	x [m]	z [m]	theta [rad]	
	begin CHEAPIE	1	0.000000	-37.439112	-298.248196	0.284123
	begin B38	1	0.000000	-37.439112	-298.248196	0.284123
	begin QUADB38	1	0.000000	-37.439112	-298.248196	0.284123
	begin FBPM	1	0.000000	-37.439112	-298.248196	0.284123
1	DBPMIN	1	0.260655	-37.366046	-297.997991	0.284123
2	HBPM	1	0.260655	-37.366046	-297.997991	0.284123
3	DBPMOUT	1	0.460680	-37.309976	-297.805986	0.284123
	end FBPM	1	0.460680	-37.309976	-297.805986	0.284123
	begin QB38	1	0.460680	-37.309976	-297.805986	0.284123
5	HQF66	1	1.300150	-37.074659	-297.000172	0.284123
6	MQB38	1	1.300150	-37.074659	-297.000172	0.284123
7	HQF66	2	2.139620	-36.839342	-296.194358	0.284123
	end QB38	1	2.139620	-36.839342	-296.194358	0.284123
9	DQOUT	1	2.311400	-36.791189	-296.029465	0.284123
	end QUADB38	1	2.311400	-36.791189	-296.029465	0.284123
	begin PACKB38	1	2.311400	-36.791189	-296.029465	0.284123
10	DPACKIN	1	2.454275	-36.751139	-295.892318	0.284123
12	QTB38	1	3.216275	-36.537538	-295.160869	0.284123
14	TSF	1	3.216275	-36.537538	-295.160869	0.284123
15	HCORR	1	3.216275	-36.537538	-295.160869	0.284123
16	DPACKU2D	1	3.622675	-36.423618	-294.770762	0.284123
17	TX	1	3.622675	-36.423618	-294.770762	0.284123
18	DPACKOUT	1	4.140200	-36.278547	-294.273986	0.284123
	end PACKB38	1	4.140200	-36.278547	-294.273986	0.284123
	end B38	1	4.140200	-36.278547	-294.273986	0.284123
	begin DIPOLE	1	4.140200	-36.278547	-294.273986	0.284123
	end DIPOLE	1	10.541000	-34.509259	-288.122595	0.276006
	begin DIPOLE	2	10.541000	-34.509259	-288.122595	0.276006
	end DIPOLE	2	16.941800	-32.789964	-281.957044	0.267888
	begin DIPOLE	3	16.941800	-32.789964	-281.957044	0.267888
	end DIPOLE	3	23.342600	-31.120776	-275.777739	0.259770
	begin DIPOLE	4	23.342600	-31.120776	-275.777739	0.259770
	end DIPOLE	4	29.743400	-29.501805	-269.585088	0.251652
	begin B39	1	29.743400	-29.501805	-269.585088	0.251652
	begin QUADB39	1	29.743400	-29.501805	-269.585088	0.251652
	begin DBPM	1	29.743400	-29.501805	-269.585088	0.251652
47	DBPMIN	2	30.004055	-29.436901	-269.332643	0.251652
48	V BPM	1	30.004055	-29.436901	-269.332643	0.251652
49	DBPMOUT	2	30.204080	-29.387093	-269.138918	0.251652
	end DBPM	1	30.204080	-29.387093	-269.138918	0.251652
	begin QB39	1	30.204080	-29.387093	-269.138918	0.251652
51	HQD66	1	31.043550	-29.178062	-268.325889	0.251652
52	MQB39	1	31.043550	-29.178062	-268.325889	0.251652
53	HQD66	2	31.883020	-28.969030	-267.512861	0.251652
	end QB39	1	31.883020	-28.969030	-267.512861	0.251652
55	DQOUT	2	32.054800	-28.926256	-267.346491	0.251652
	end QUADB39	1	32.054800	-28.926256	-267.346491	0.251652
	begin PACKB39	1	32.054800	-28.926256	-267.346491	0.251652
56	DPINSLOC	1	32.223075	-28.884355	-267.183517	0.251652
58	QTB39	1	32.985075	-28.694614	-266.445518	0.251652
60	TSD	1	32.985075	-28.694614	-266.445518	0.251652
61	VCORR	1	32.985075	-28.694614	-266.445518	0.251652
62	DPOUT5LO	1	33.147000	-28.654293	-266.288693	0.251652
	end PACKB39	1	33.147000	-28.654293	-266.288693	0.251652
	begin TABGVTAB	1	33.147000	-28.654293	-266.288693	0.251652
63	DSSINF	1	33.439100	-28.581559	-266.005793	0.251652
64	DTAB	1	33.610550	-28.538868	-265.839744	0.251652
65	DGV3	1	33.712150	-28.513569	-265.741344	0.251652
66	DTAB	2	33.883600	-28.470877	-265.575294	0.251652
	end TABGVTAB	1	33.883600	-28.470877	-265.575294	0.251652
	end B39	1	33.883600	-28.470877	-265.575294	0.251652
	begin DIPOLE	5	33.883600	-28.470877	-265.575294	0.251652
	end DIPOLE	5	40.284400	-26.902229	-259.369705	0.243534
	begin DIPOLE	6	40.284400	-26.902229	-259.369705	0.243534
	end DIPOLE	6	46.685200	-25.384009	-253.151586	0.235417
	begin DIPOLE	7	46.685200	-25.384009	-253.151586	0.235417
	end DIPOLE	7	53.086000	-23.916315	-246.921347	0.227299
	begin DIPOLE	8	53.086000	-23.916315	-246.921347	0.227299
	end DIPOLE	8	59.486800	-22.499245	-240.679400	0.219181
	begin B42	1	59.486800	-22.499245	-240.679400	0.219181
	begin QUADB42	1	59.486800	-22.499245	-240.679400	0.219181
	begin FBPM	2	59.486800	-22.499245	-240.679400	0.219181
95	DBPMIN	3	59.747455	-22.442571	-240.424981	0.219181
96	HBPM	2	59.747455	-22.442571	-240.424981	0.219181
97	DBPMOUT	3	59.947480	-22.399079	-240.229741	0.219181
	end FBPM	2	59.947480	-22.399079	-240.229741	0.219181

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begin QB42      1   59.947480   -22.399079   -240.229741   0.219181
   99 HQF66      3   60.786950   -22.216553   -239.410355   0.219181
  100 MQB42      1   60.786950   -22.216553   -239.410355   0.219181
  101 HQF66      4   61.626420   -22.034027   -238.590968   0.219181
end QB42      1   61.626420   -22.034027   -238.590968   0.219181
  103 DQOUT      3   61.798200   -21.996677   -238.423298   0.219181
end QUADB42    1   61.798200   -21.996677   -238.423298   0.219181
begin PACKB42   1   61.798200   -21.996677   -238.423298   0.219181
  104 DPACKIN2   1   61.968431   -21.959663   -238.257140   0.219181
  106 QTB42      1   62.603431   -21.821595   -237.637332   0.219181
  108 DPACKU2D   1   63.106249   -21.712267   -237.146543   0.219181
  109 TSF        2   63.106249   -21.712267   -237.146543   0.219181
  110 HCORR      2   63.106249   -21.712267   -237.146543   0.219181
  111 DPACKOUT   1   63.627000   -21.599040   -236.638250   0.219181
end PACKB42    1   63.627000   -21.599040   -236.638250   0.219181
end B42        1   63.627000   -21.599040   -236.638250   0.219181

begin DIPOLE    9   63.627000   -21.599040   -236.638250   0.219181
end DIPOLE    9   70.027800   -20.232688   -230.385005   0.211063
begin DIPOLE   10   70.027800   -20.232688   -230.385005   0.211063
end DIPOLE   10   76.428600   -18.917142   -224.120874   0.202945
begin DIPOLE   11   76.428600   -18.917142   -224.120874   0.202945
end DIPOLE   11   82.829400   -17.652490   -217.846271   0.194827
begin DIPOLE   12   82.829400   -17.652490   -217.846271   0.194827
end DIPOLE   12   89.230200   -16.438815   -211.561608   0.186710

begin B43      1   89.230200   -16.438815   -211.561608   0.186710
begin QUADB43  1   89.230200   -16.438815   -211.561608   0.186710
begin DBPM      2   89.230200   -16.438815   -211.561608   0.186710
  140 DBPMIN    4   89.490855   -16.390430   -211.305483   0.186710
  141 VBPM      2   89.490855   -16.390430   -211.305483   0.186710
  142 DBPMOUT   4   89.690880   -16.353300   -211.108934   0.186710
end DBPM      2   89.690880   -16.353300   -211.108934   0.186710
begin QB43      1   89.690880   -16.353300   -211.108934   0.186710
  144 HQD66     3   90.530350   -16.197472   -210.284054   0.186710
  145 MQB43     1   90.530350   -16.197472   -210.284054   0.186710
  146 HQD66     4   91.369820   -16.041644   -209.459174   0.186710
end QB43      1   91.369820   -16.041644   -209.459174   0.186710
  148 DQOUT     4   91.541600   -16.009757   -209.290379   0.186710
end QUADB43   1   91.541600   -16.009757   -209.290379   0.186710
begin PACKB43  1   91.541600   -16.009757   -209.290379   0.186710
  149 DPACKIN2  2   91.711831   -15.978158   -209.123107   0.186710
  151 QTB43     1   92.346831   -15.860285   -208.499143   0.186710
  153 DPACKU2D  2   92.849649   -15.766949   -208.005064   0.186710
  154 TSD       2   92.849649   -15.766949   -208.005064   0.186710
  155 VCORR     2   92.849649   -15.766949   -208.005064   0.186710
  156 DPACKOUT  2   93.370400   -15.670283   -207.493363   0.186710
end PACKB43   1   93.370400   -15.670283   -207.493363   0.186710
end B43        1   93.370400   -15.670283   -207.493363   0.186710

begin DIPOLE   13   93.370400   -15.670283   -207.493363   0.186710
end DIPOLE   13   99.771200   -14.507666   -201.199055   0.178592
begin DIPOLE   14   99.771200   -14.507666   -201.199055   0.178592
end DIPOLE   14   106.172000   -13.396182   -194.895516   0.170474
begin DIPOLE   15   106.172000   -13.396182   -194.895516   0.170474
end DIPOLE   15   112.572800   -12.335905   -188.583162   0.162356
begin DIPOLE   16   112.572800   -12.335905   -188.583162   0.162356
end DIPOLE   16   118.973600   -11.326905   -182.262410   0.154238

begin B44      1   118.973600   -11.326905   -182.262410   0.154238
begin QUADB44  1   118.973600   -11.326905   -182.262410   0.154238
begin FBPM     3   118.973600   -11.326905   -182.262410   0.154238
  185 DBPMIN    5   119.234255   -11.286861   -182.004849   0.154238
  186 HBPM     3   119.234255   -11.286861   -182.004849   0.154238
  187 DBPMOUT   5   119.434280   -11.256131   -181.807199   0.154238
end FBPM     3   119.434280   -11.256131   -181.807199   0.154238
begin QB44     1   119.434280   -11.256131   -181.807199   0.154238
  189 HQF66     5   120.273750   -11.127166   -180.977694   0.154238
  190 MQB44     1   120.273750   -11.127166   -180.977694   0.154238
  191 HQF66     6   121.113220   -10.998200   -180.148190   0.154238
end QB44     1   121.113220   -10.998200   -180.148190   0.154238
  193 DQOUT     5   121.285000   -10.971810   -179.978449   0.154238
end QUADB44   1   121.285000   -10.971810   -179.978449   0.154238
begin PACKB44  1   121.285000   -10.971810   -179.978449   0.154238
  194 DPACKIN2  3   121.455231   -10.945658   -179.810239   0.154238
  196 QTB44     1   122.090231   -10.848104   -179.182777   0.154238
  198 DPACKU2D  3   122.593049   -10.770857   -178.685928   0.154238
  199 TSF       3   122.593049   -10.770857   -178.685928   0.154238
  200 HCORR     3   122.593049   -10.690856   -178.171359   0.154238
  201 DPACKOUT  3   123.113800   -10.690856   -178.171359   0.154238
end PACKB44   1   123.113800   -10.690856   -178.171359   0.154238
end B44        1   123.113800   -10.690856   -178.171359   0.154238

begin DIPOLE   17   123.113800   -10.690856   -178.171359   0.154238
end DIPOLE   17   129.514600   -9.733199   -171.842624   0.146121
begin DIPOLE   18   129.514600   -9.733199   -171.842624   0.146121
end DIPOLE   18   135.915400   -8.826949   -165.506323   0.138003
begin DIPOLE   19   135.915400   -8.826949   -165.506323   0.138003
end DIPOLE   19   142.316200   -7.972165   -159.162874   0.129885
begin DIPOLE   20   142.316200   -7.972165   -159.162874   0.129885
end DIPOLE   20   148.717000   -7.168903   -152.812696   0.121767

begin B45      1   148.717000   -7.168903   -152.812696   0.121767
  230 BPMB45   1   149.148775   -7.116457   -152.384118   0.121767
begin QUADB45  1   149.148775   -7.116457   -152.384118   0.121767
  231 DLB6     1   149.316237   -7.096116   -152.217896   0.121767
begin QB45     1   149.316237   -7.096116   -152.217896   0.121767

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233 HQB45      1   150.017150    -7.010978   -151.522173   0.121767
234 MQB45      1   150.017150    -7.010978   -151.522173   0.121767
235 HQB45      2   150.718063    -6.925841   -150.826450   0.121767
end QB45       1   150.718063    -6.925841   -150.826450   0.121767
237 DLB5       1   150.998581    -6.891767   -150.548009   0.121767
end QUADB45    1   150.998581    -6.891767   -150.548009   0.121767
begin PACKB45  1   150.998581    -6.891767   -150.548009   0.121767
238 DSP4       1   151.503406    -6.830448   -150.046922   0.121767
239 VCORR      3   151.503406    -6.830448   -150.046922   0.121767
240 TSD        3   151.503406    -6.830448   -150.046922   0.121767
241 DSP4515    1   152.120600    -6.755480   -149.434298   0.121767
end PACKB45    1   152.120600    -6.755480   -149.434298   0.121767
242 FEED       1   152.857200    -6.666008   -148.703152   0.121767
end B45        1   152.857200    -6.666008   -148.703152   0.121767

begin DIPOLE   21  152.857200    -6.666008   -148.703152   0.121767
end DIPOLE    21  159.258000    -5.914321   -142.346662   0.113649
begin DIPOLE   22  159.258000    -5.914321   -142.346662   0.113649
end DIPOLE    22  165.658800    -5.214260   -135.984279   0.105532
begin DIPOLE   23  165.658800    -5.214260   -135.984279   0.105532
end DIPOLE    23  172.059600    -4.565870   -129.616424   0.097414
begin DIPOLE   24  172.059600    -4.565870   -129.616424   0.097414
end DIPOLE    24  178.460400    -3.969194   -123.243514   0.089296
begin DIPOLE   25  178.460400    -3.969194   -123.243514   0.089296
end DIPOLE    25  184.861200    -3.424271   -116.865971   0.081178

begin B46       1   184.861200    -3.424271   -116.865971   0.081178
begin QUADB46  1   184.861200    -3.424271   -116.865971   0.081178
278 DLB6       2   185.028662    -3.410692   -116.699061   0.081178
begin QB46       1   185.028662    -3.410692   -116.699061   0.081178
280 HQB46      1   185.729575    -3.353855   -116.000456   0.081178
281 MQB46      1   185.729575    -3.353855   -116.000456   0.081178
282 HQB46      2   186.430488    -3.297019   -115.301851   0.081178
end QB46       1   186.430488    -3.297019   -115.301851   0.081178
284 DLB5       2   186.711006    -3.274272   -115.022257   0.081178
end QUADB46   1   186.711006    -3.274272   -115.022257   0.081178
begin PACKB46  1   186.711006    -3.274272   -115.022257   0.081178
285 DSP4       2   187.215831    -3.233336   -114.519094   0.081178
286 HCORR      4   187.215831    -3.233336   -114.519094   0.081178
287 TSF        4   187.215831    -3.233336   -114.519094   0.081178
288 DSP3       1   187.753676    -3.189723   -113.983021   0.081178
289 HBPM       4   187.753676    -3.189723   -113.983021   0.081178
290 DSP0       1   188.137851    -3.158571   -113.600111   0.081178
end PACKB46   1   188.137851    -3.158571   -113.600111   0.081178
end B46        1   188.137851    -3.158571   -113.600111   0.081178

begin DIPOLE   26  188.137851    -3.158571   -113.600111   0.081178
end DIPOLE   26  194.538651    -2.665437   -107.218354   0.073060
begin DIPOLE   27  194.538651    -2.665437   -107.218354   0.073060
end DIPOLE   27  200.939451    -2.224124   -100.832805   0.064942
begin DIPOLE   28  200.939451    -2.224124   -100.832805   0.064942
end DIPOLE   28  207.340251    -1.834663   -94.443884   0.056825
begin DIPOLE   29  207.340251    -1.834663   -94.443884   0.056825
end DIPOLE   29  213.741051    -1.497077   -88.052011   0.048707

begin B47       1   213.741051    -1.497077   -88.052011   0.048707
begin QUADB47  1   213.741051    -1.497077   -88.052011   0.048707
319 HEAD       1   214.219175    -1.473799   -87.574455   0.048707
begin QB47       1   214.219175    -1.473799   -87.574455   0.048707
321 HQB47      1   214.904975    -1.440409   -86.889468   0.048707
322 MQB47      1   214.904975    -1.440409   -86.889468   0.048707
323 HQB47      2   215.590775    -1.407019   -86.204481   0.048707
end QB47       1   215.590775    -1.407019   -86.204481   0.048707
325 BUTT       1   216.181955    -1.378236   -85.614002   0.048707
end QUADB47   1   216.181955    -1.378236   -85.614002   0.048707
begin PACKB47  1   216.181955    -1.378236   -85.614002   0.048707
326 DSP4       3   216.686780    -1.353657   -85.109776   0.048707
327 VCORR      4   216.686780    -1.353657   -85.109776   0.048707
328 TSD        4   216.686780    -1.353657   -85.109776   0.048707
329 DSP3       2   217.224625    -1.327470   -84.572569   0.048707
330 VBPM       3   217.224625    -1.327470   -84.572569   0.048707
331 DSP0       2   217.608800    -1.308766   -84.188850   0.048707
end PACKB47   1   217.608800    -1.308766   -84.188850   0.048707
end B47        1   217.608800    -1.308766   -84.188850   0.048707

begin DIPOLE   30  217.608800    -1.308766   -84.188850   0.048707
end DIPOLE   30  224.009600    -1.023079   -77.794447   0.040589
begin DIPOLE   31  224.009600    -1.023079   -77.794447   0.040589
end DIPOLE   31  230.410400    -0.789310   -71.397937   0.032471

346 DR48UP     1   233.731400    -0.681491   -68.078687   0.032471

begin B48       1   233.731400    -0.681491   -68.078687   0.032471
begin PACKB48  1   233.731400    -0.681491   -68.078687   0.032471
347 DSP4       4   234.236225    -0.665102   -67.574129   0.032471
348 HCORR      5   234.236225    -0.665102   -67.574129   0.032471
349 TSF        5   234.236225    -0.665102   -67.574129   0.032471
350 DSP3       3   234.774070    -0.647641   -67.036567   0.032471
351 HBPM       5   234.774070    -0.647641   -67.036567   0.032471
352 DSP0       3   235.158245    -0.635168   -66.652595   0.032471
end PACKB48   1   235.158245    -0.635168   -66.652595   0.032471
begin QUADB48  1   235.158245    -0.635168   -66.652595   0.032471
353 BUTT       2   235.749425    -0.615975   -66.061726   0.032471
begin QB48       1   235.749425    -0.615975   -66.061726   0.032471
355 HQB48      1   236.701925    -0.585052   -65.109728   0.032471
356 MQB48      1   236.701925    -0.585052   -65.109728   0.032471
357 HQB48      2   237.654425    -0.554128   -64.157731   0.032471

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end QB48      1  237.654425   -0.554128   -64.157731   0.032471
  359 HEAD      2  238.132549   -0.538606   -63.679859   0.032471
end QUADB48    1  238.132549   -0.538606   -63.679859   0.032471
end B48       1  238.132549   -0.538606   -63.679859   0.032471

begin DIPOLE   32  238.132549   -0.538606   -63.679859   0.032471
end DIPOLE   32  244.533349   -0.356769   -57.281661   0.024353
begin DIPOLE   33  244.533349   -0.356769   -57.281661   0.024353
end DIPOLE   33  250.934149   -0.226877   -50.882198   0.016236
begin DIPOLE   34  250.934149   -0.226877   -50.882198   0.016236
end DIPOLE   34  257.334949   -0.148939   -44.481892   0.008118
begin DIPOLE   35  257.334949   -0.148939   -44.481892   0.008118
end DIPOLE   35  263.735749   -0.122959   -38.081164   0.000000

  388 DR48C0    1  265.275650   -0.122959   -36.541263   0.000000
begin ESEPSU   1  265.275650   -0.122959   -36.541263   0.000000
  389 CBYPD     1  265.704275   -0.122959   -36.112638   0.000000
  390 SEPEND    1  266.025052   -0.122959   -35.791861   0.000000
  392 B49VESEP   1  268.596802   -0.122959   -33.220111   0.000000
  394 SEPMID    1  268.784127   -0.122959   -33.032786   0.000000
  396 B49HESEP   1  271.355877   -0.122959   -30.461036   0.000000
  398 SEPMID    2  271.543202   -0.122959   -30.237311   0.000000
  400 B49HESEP   2  274.114952   -0.122959   -27.701961   0.000000
  402 SEPEND    2  274.435729   -0.122959   -27.381184   0.000000
end ESEPSU    1  274.435729   -0.122959   -27.381184   0.000000

  403 CBYPU     1  274.737354   -0.122959   -27.079559   0.000000
  404 FEED      2  275.473954   -0.122959   -26.342959   0.000000

begin TRIPLEU   1  275.473954   -0.122959   -26.342959   0.000000
begin Q3D      1  275.473954   -0.122959   -26.342959   0.000000
  405 HEAD      3  275.952078   -0.122959   -25.864835   0.000000
  406 MQQ      29  275.952078   -0.122959   -25.864835   0.000000
  407 Q3DX     1  276.564853   -0.122959   -25.252060   0.000000
  408 BVMAX     1  276.564853   -0.122959   -25.252060   0.000000
  409 Q3DX     2  277.177628   -0.122959   -24.639285   0.000000
  410 MQD3     1  277.177628   -0.122959   -24.639285   0.000000
  411 Q3DX     3  277.790403   -0.122959   -24.026510   0.000000
  412 Q3DX     4  278.403178   -0.122959   -23.413735   0.000000
  413 MQQ      30  278.403178   -0.122959   -23.413735   0.000000
  414 BUTT      3  278.994358   -0.122959   -22.822555   0.000000
end Q3D       1  278.994358   -0.122959   -22.822555   0.000000

begin TPACKU   1  278.994358   -0.122959   -22.822555   0.000000
  415 DSP4      5  279.499183   -0.122959   -22.317730   0.000000
  416 HCORR     6  279.499183   -0.122959   -22.317730   0.000000
  417 QTU       1  279.499183   -0.122959   -22.317730   0.000000
  418 VCORR     5  279.499183   -0.122959   -22.317730   0.000000
  419 DSP3      4  280.037028   -0.122959   -21.779885   0.000000
  420 HBPM      6  280.037028   -0.122959   -21.779885   0.000000
  421 DSP2      1  280.265628   -0.122959   -21.551285   0.000000
  422 VBPM      4  280.265628   -0.122959   -21.551285   0.000000
  423 DSP1      1  280.421203   -0.122959   -21.395710   0.000000
end TPACKU    1  280.421203   -0.122959   -21.395710   0.000000

begin Q2F      1  280.421203   -0.122959   -21.395710   0.000000
  424 HEAD      4  280.899326   -0.122959   -20.917586   0.000000
  425 MQQ      31  280.899326   -0.122959   -20.917586   0.000000
  426 Q2FX     1  282.001051   -0.122959   -19.815861   0.000000
  427 Q2FX     2  283.102776   -0.122959   -18.714136   0.000000
  428 BHMAX     1  283.102776   -0.122959   -18.714136   0.000000
  429 MQF2     1  283.102776   -0.122959   -18.714136   0.000000
  430 Q2FX     3  284.204501   -0.122959   -17.612411   0.000000
  431 Q2FX     4  285.306226   -0.122959   -16.510686   0.000000
  432 MQQ      32  285.306226   -0.122959   -16.510686   0.000000
  433 BUTT      4  285.897406   -0.122959   -15.919506   0.000000
end Q2F       1  285.897406   -0.122959   -15.919506   0.000000
begin Q1D      1  285.897406   -0.122959   -15.919506   0.000000
  434 HEAD      5  286.375530   -0.122959   -15.441382   0.000000
  435 MQQ      33  286.375530   -0.122959   -15.441382   0.000000
  436 Q1DX     1  286.988305   -0.122959   -14.828607   0.000000
  437 Q1DX     2  287.601080   -0.122959   -14.215832   0.000000
  438 MQD1     1  287.601080   -0.122959   -14.215832   0.000000
  439 Q1DX     3  288.213855   -0.122959   -13.603057   0.000000
  440 Q1DX     4  288.826630   -0.122959   -12.990282   0.000000
  441 MQQ      34  288.826630   -0.122959   -12.990282   0.000000
  442 BUTT      5  289.417810   -0.122959   -12.399102   0.000000
end Q1D       1  289.417810   -0.122959   -12.399102   0.000000

begin TWOBPM   1  289.417810   -0.122959   -12.399102   0.000000
  443 BPMIN    1  289.557510   -0.122959   -12.259402   0.000000
  444 HBPM     7  289.557510   -0.122959   -12.259402   0.000000
  445 BPMMID   1  289.678160   -0.122959   -12.138752   0.000000
  446 VBPM     5  289.678160   -0.122959   -12.138752   0.000000
  447 BPMOUT   1  289.817860   -0.122959   -11.999052   0.000000
end TWOBPM    1  289.817860   -0.122959   -11.999052   0.000000
end TRIPLEU   1  289.817860   -0.122959   -11.999052   0.000000

begin GOAWAY   1  289.817860   -0.122959   -11.999052   0.000000
end GOAWAY    1  301.815906   -0.122959   -0.001006   0.000000
458 STAR    1  301.815906   -0.122959   -0.001006   0.000000
begin GOAWAY   2  301.815906   -0.122959   -0.001006   0.000000
end GOAWAY    2  313.813952   -0.122959   11.997040   0.000000

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begin TRIPLED    1  313.813952   -0.122959   11.997040   0.000000
begin TWOBPM     2  313.813952   -0.122959   11.997040   0.000000
  469 BPMIN      2  313.953652   -0.122959   12.136740   0.000000
  470 HBPM       8  313.953652   -0.122959   12.136740   0.000000
  471 BPMMID    2  314.074302   -0.122959   12.257390   0.000000
  472 VBPM       6  314.074302   -0.122959   12.257390   0.000000
  473 BPMOUT     2  314.214002   -0.122959   12.397090   0.000000
end  TWOBPM     2  314.214002   -0.122959   12.397090   0.000000

begin Q1F        1  314.214002   -0.122959   12.397090   0.000000
  474 BUTT       6  314.805182   -0.122959   12.988270   0.000000
  475 MQQ        35 314.805182   -0.122959   12.988270   0.000000
  476 Q1FX       1  315.417957   -0.122959   13.601045   0.000000
  477 Q1FX       2  316.030732   -0.122959   14.213820   0.000000
  478 MQF1       1  316.030732   -0.122959   14.213820   0.000000
  479 Q1FX       3  316.643507   -0.122959   14.826595   0.000000
  480 Q1FX       4  317.256282   -0.122959   15.439370   0.000000
  481 MQQ        36 317.256282   -0.122959   15.439370   0.000000
  482 HEAD       6  317.734406   -0.122959   15.917494   0.000000
end  Q1F        1  317.734406   -0.122959   15.917494   0.000000
begin Q2D        1  317.734406   -0.122959   15.917494   0.000000
  483 BUTT       7  318.325586   -0.122959   16.508673   0.000000
  484 MQQ        37 318.325586   -0.122959   16.508673   0.000000
  485 Q2DX       1  319.427311   -0.122959   17.610398   0.000000
  486 Q2DX       2  320.529036   -0.122959   18.712123   0.000000
  487 MQD2       1  320.529036   -0.122959   18.712123   0.000000
  488 BVMAX      2  320.529036   -0.122959   18.712123   0.000000
  489 Q2DX       3  321.630761   -0.122959   19.813848   0.000000
  490 Q2DX       4  322.732486   -0.122959   20.915573   0.000000
  491 MQQ        38 322.732486   -0.122959   20.915573   0.000000
  492 HEAD       7  323.210610   -0.122959   21.393697   0.000000
end  Q2D        1  323.210610   -0.122959   21.393697   0.000000

begin TPACKD     1  323.210610   -0.122959   21.393697   0.000000
  493 DSP1       2  323.366185   -0.122959   21.549272   0.000000
  494 VBPM       7  323.366185   -0.122959   21.549272   0.000000
  495 DSP2       2  323.594785   -0.122959   21.777872   0.000000
  496 HBPM       9  323.594785   -0.122959   21.777872   0.000000
  497 DSP3       5  324.132630   -0.122959   22.315717   0.000000
  498 VCORR      6  324.132630   -0.122959   22.315717   0.000000
  499 QTD        1  324.132630   -0.122959   22.315717   0.000000
  500 HCORR      7  324.132630   -0.122959   22.315717   0.000000
  501 DSP4       6  324.637455   -0.122959   22.820542   0.000000
end  TPACKD     1  324.637455   -0.122959   22.820542   0.000000

begin Q3F        1  324.637455   -0.122959   22.820542   0.000000
  502 BUTT       8  325.228635   -0.122959   23.411722   0.000000
  503 MQQ        39 325.228635   -0.122959   23.411722   0.000000
  504 Q3FX       1  325.841410   -0.122959   24.024497   0.000000
  505 Q3FX       2  326.454185   -0.122959   24.637272   0.000000
  506 MQF3       1  326.454185   -0.122959   24.637272   0.000000
  507 Q3FX       3  327.066960   -0.122959   25.250047   0.000000
  508 BHMAX      2  327.066960   -0.122959   25.250047   0.000000
  509 Q3FX       4  327.679735   -0.122959   25.862822   0.000000
  510 MQQ        40 327.679735   -0.122959   25.862822   0.000000
  511 HEAD       8  328.157859   -0.122959   26.340946   0.000000
end  Q3F        1  328.157859   -0.122959   26.340946   0.000000
end  TRIPLED     1  328.157859   -0.122959   26.340946   0.000000

  512 FEED       3  328.894459   -0.122959   27.077546   0.000000
  513 CBYPU      2  329.196084   -0.122959   27.379171   0.000000

begin ESEPSD     1  329.196084   -0.122959   27.379171   0.000000
  514 SEPEND     3  329.516861   -0.122959   27.699948   0.000000
  516 C11VESEP   1  332.088611   -0.122959   30.271698   0.000000
  518 SEPMID     3  332.275936   -0.122959   30.459023   0.000000
  520 C11VESEP   2  334.847686   -0.122959   33.030773   0.000000
  522 SEPMID     4  335.035011   -0.122959   33.218098   0.000000
  524 C11HESEP   1  337.606761   -0.122959   35.789848   0.000000
  526 SEPEND     4  337.927538   -0.122959   36.110625   0.000000
  527 CBYPD      2  338.356163   -0.122959   36.539250   0.000000
end  ESEPSD     1  338.356163   -0.122959   36.539250   0.000000

begin DIPOLE     36 338.356163   -0.122959   36.539250   0.000000
end  DIPOLE     36 344.756963   -0.148939   42.939978   -0.008118
begin DIPOLE     37 344.756963   -0.148939   42.939978   -0.008118
end  DIPOLE     37 351.157763   -0.226877   49.340285   -0.016236
begin DIPOLE     38 351.157763   -0.226877   49.340285   -0.016236
end  DIPOLE     38 357.558563   -0.356769   55.739748   -0.024353
begin DIPOLE     39 357.558563   -0.356769   55.739748   -0.024353
end  DIPOLE     39 363.959363   -0.538606   62.137945   -0.032471

begin C12        1  363.959363   -0.538606   62.137945   -0.032471
begin PACKC12    1  363.959363   -0.538606   62.137945   -0.032471
  556 DSP4       7  364.464188   -0.554995   62.642504   -0.032471
  557 VCORR      7  364.464188   -0.554995   62.642504   -0.032471
  558 TSD         5  364.464188   -0.554995   62.642504   -0.032471
  559 DSP3       6  365.002033   -0.572457   63.180065   -0.032471
  560 VBPM       8  365.002033   -0.572457   63.180065   -0.032471
  561 DSP0       4  365.386208   -0.584929   63.564038   -0.032471
end  PACKC12    1  365.386208   -0.584929   63.564038   -0.032471
begin QUADC12   1  365.386208   -0.584929   63.564038   -0.032471
  562 BUTT       9  365.977388   -0.604122   64.154906   -0.032471
begin QC12       1  365.977388   -0.604122   64.154906   -0.032471
  564 HQC12      1  366.929888   -0.635046   65.106904   -0.032471
  565 MQC12      1  366.929888   -0.635046   65.106904   -0.032471
  566 HQC12      2  367.882388   -0.665969   66.058902   -0.032471

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end QC12      1  367.882388   -0.665969   66.058902   -0.032471
  568 HEAD      9  368.360512   -0.681491   66.536774   -0.032471
end QUADC12    1  368.360512   -0.681491   66.536774   -0.032471
end C12       1  368.360512   -0.681491   66.536774   -0.032471

begin DIPOLE   40  368.360512   -0.681491   66.536774   -0.032471
end DIPOLE    40  374.761312   -0.915261   72.933284   -0.040589
begin DIPOLE   41  374.761312   -0.915261   72.933284   -0.040589
end DIPOLE    41  381.162112   -1.200948   79.327687   -0.048707
begin DIPOLE   42  381.162112   -1.200948   79.327687   -0.048707
end DIPOLE    42  387.562912   -1.538533   85.719559   -0.056825

begin C13      1  387.562912   -1.538533   85.719559   -0.056825
begin QUADC13  1  387.562912   -1.538533   85.719559   -0.056825
  590 HEAD     10  388.041035   -1.565688   86.196911   -0.056825
begin QC13     1  388.041035   -1.565688   86.196911   -0.056825
  592 HQC13    1  388.726835   -1.604637   86.881604   -0.056825
  593 MQC13    1  388.726835   -1.604637   86.881604   -0.056825
  594 HQC13    2  389.412635   -1.643587   87.566297   -0.056825
end QC13      1  389.412635   -1.643587   87.566297   -0.056825
  596 BUTT     10  390.003815   -1.677162   88.156523   -0.056825
end QUADC13   1  390.003815   -1.677162   88.156523   -0.056825
begin PACKC13  1  390.003815   -1.677162   88.156523   -0.056825
  597 DSP4     8  390.508640   -1.705833   88.660533   -0.056825
  598 HCORR    8  390.508640   -1.705833   88.660533   -0.056825
  599 TSF      6  390.508640   -1.705833   88.660533   -0.056825
  600 DSP3     7  391.046485   -1.736380   89.197510   -0.056825
  601 HBPM    10  391.046485   -1.736380   89.197510   -0.056825
  602 DSP0     5  391.430660   -1.758199   89.581065   -0.056825
end PACKC13   1  391.430660   -1.758199   89.581065   -0.056825
end C13       1  391.430660   -1.758199   89.581065   -0.056825

begin DIPOLE   43  391.430660   -1.758199   89.581065   -0.056825
end DIPOLE   43  397.831460   -2.147660   95.969986   -0.064942
begin DIPOLE   44  397.831460   -2.147660   95.969986   -0.064942
end DIPOLE   44  404.232260   -2.588973  102.355536   -0.073060
begin DIPOLE   45  404.232260   -2.588973  102.355536   -0.073060
end DIPOLE   45  410.633060   -3.082107  108.737292   -0.081178
begin DIPOLE   46  410.633060   -3.082107  108.737292   -0.081178
end DIPOLE   46  417.033860   -3.627030  115.114835   -0.089296

begin C14      1  417.033860   -3.627030  115.114835   -0.089296
begin QUADC14  1  417.033860   -3.627030  115.114835   -0.089296
  631 DLB6     3  417.201322   -3.641963  115.281630   -0.089296
begin QC14     1  417.201322   -3.641963  115.281630   -0.089296
  633 HQC14    1  417.902235   -3.704469  115.979750   -0.089296
  634 MQC14    1  417.902235   -3.704469  115.979750   -0.089296
  635 HQC14    2  418.603148   -3.766974  116.677871   -0.089296
end QC14      1  418.603148   -3.766974  116.677871   -0.089296
  637 DLB5     3  418.883666   -3.791990  116.957271   -0.089296
end QUADC14   1  418.883666   -3.791990  116.957271   -0.089296
begin PACKC14  1  418.883666   -3.791990  116.957271   -0.089296
  638 DSP4     9  419.388491   -3.837009  117.460085   -0.089296
  639 VCORR    8  419.388491   -3.837009  117.460085   -0.089296
  640 TSD      6  419.388491   -3.837009  117.460085   -0.089296
  641 DSP3     8  419.926336   -3.884973  117.995787   -0.089296
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